he has so many that they block each other's path" is practically to abandon the position which has been painfully and slowly gained by those who have thought and written on instinct. Instinct is a definite and special manifestation of innate tendency: here the innate tendency is not manifested in this definite and special way, but is thwarted. To call both manifestation and non-manifestation alike instinct is, in our view, a retrograde step, which we regret that a psychologist of Prof. James's insight and influence should have taken.

We cannot, however, leave the book with a note of dissent; for we find far more in this text-book to agree with than to dissent from. Whether we agree or dissent, we always find Prof. James full of stimulating thought; and we advise all who are interested in psychology to read at least the chapters on "Habit," "The Stream of Consciousness," and "The Self," if they read no more.

C. LL. M.

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## DYNAMICS OF ROTATION.

*Dynamics of Rotation: an Elementary Introduction to Rigid Dynamics.* By A. M. Worthington. Pp. 155. (London: Longmans, Green, and Co., 1892.)

*Spinning Tops.* By John Perry. Pp. 136. (London: Society for Promoting Christian Knowledge, 1890.)

THE persistence of spinning tops and of running bicycles in rearing themselves erect are common examples of a wide class of dynamical phenomena which are influenced or governed by the presence of rapidly rotating parts, and which have a prominent place in all departments of physical science, from the relations of the systems of the stars down to molecular actions.

In formal treatises on abstract dynamics we are accustomed to find the properties of freely rotating systems relegated to an advanced part of the development of the subject, and expounded with all the powerful help which mathematical analysis can afford. If we are to have a complete theory of the circumstances which determine the stability and transformations of rotational motions, this analytical aid is none too extensive. But there is another mode of approaching a physical subject, which consists in learning from observation and properly varied experiment what are the phenomena that are persistent and stable, and then applying known dynamical principles to the elucidation of the properties of the motions thus known in fact to exist—a problem which need not in those simpler cases which are fundamental require any great amount of analytical knowledge.

As an additional reason for the customary abstract development of dynamics, there may perhaps be counted the historical fact that the questions that were of paramount importance when dynamical principles concerning extended systems of bodies were being evolved, related to the orbital and axial motions of the heavenly bodies, and their reconciliation with the law of universal gravitation. The absence of frictional resistances, and the long duration and delicacy of astronomical observations, had led to a minute knowledge of the motions of the solar system, which taxed all the resources of Clairaut, D'Alembert, Laplace, and Lagrange, to verify and explain.

Many of the dynamical principles which are now treated as elementary and fundamental were thus come upon in special analytical investigations relating to physical astronomy. It was, for example, in this way that the principle of the conservation of angular momentum for the solar system was discovered by Laplace, and then generalized to a system with any kind of internal connections which is not subject to forces from outside it. How far a general principle of this kind, when divested of its analytical dress, enables us to see into the general causes of things is well known. A striking illustration is the *aperçu* of Prof. James Thomson, that when once the trade winds have been explained as a consequence of the earth's rotation, they involve of necessity the existence also of anti-trades or south-west winds in the temperate zone; for if the trades blew by themselves their friction against the earth would always be acting round in the same direction, and therefore would tend to stop the earth's rotation, not by wholly destroying its motion, but by transferring its angular momentum undiminished to the atmosphere, where it would continually accumulate. This simple remark thus shows that the trades blowing to the equator must be compensated by anti-trades blowing from it; and therefore also explains the existence of a region of high barometer between them. It will also occur to memory how much J. Purser, W. Thomson, and specially G. H. Darwin, have established in the tidal evolution of the earth-moon system, by studying the possibilities of development that are allowed subject to the conservation of its angular momentum and the degradation of its energy.

It has been reserved for our own half-century to bring out the wealth of general dynamical ideas that is contained in the magnificent analytical presentation by Lagrange of the results of the application of the laws of motion to systems of bodies, the number of variables or co-ordinates being of necessity (for analytical purposes) restricted to the number of degrees of freedom, and everything turning out to be expressible in terms of one fundamental function—the energy of the system. It will be apparent, on looking through Prof. Cayley's Reports on Dynamics to the British Association, how much the progress of this department of abstract dynamics was indebted to the necessities of astronomy. That science presented a problem which was in one sense quite definite and precise, on account of the smallness of the planetary masses, but which nevertheless required a minute explanation of the perturbations to which the planetary bodies are subjected owing to their mutual actions. The methods which proved comprehensive and efficient for this purpose also showed themselves, when they were examined from a more general standpoint, to reveal principles of a far-reaching character, that applied to dynamical systems however complicated. The final stage of analytical development was reached when the keen perception of Sir W. R. Hamilton saw that the whole subject could be removed from special considerations of space and time, and attached to the purely analytical treatment of a single varying action function; and the commentary of Jacobi showed precisely how to pass from this general differential analysis to the solutions of special dynamical questions.

At the present time there seems to be no danger of the interruption of progress by too close an adherence to the

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calculus. The fact is, that nearly all the problems of the numerical calculation of perturbations which were urgent at the beginning of the century, in order to bind the solar system to the scheme of universal gravitation, have now been satisfactorily disposed of. There is no longer the same need for the greatest intellectual power to set itself to put right some periodic or secular inequality, which requires all the battery of analysis that is available, and often more. New ground has been broken since then, and there is the great array of the physical sciences, all struggling to become purely dynamical, but all hampered in this by the fact that the dynamical machinery, the phenomena of matter and motion, on which they depend, are to a great extent concealed from direct observation or exploration. Under such circumstances the method of progress is to carefully cherish, and reduce into a scheme such as will appeal directly to the understanding, all the general principles which have become evolved in the course of dynamical investigations relating to problems of which the data are thoroughly known; and to use them as a key for the dynamical interpretation of more recondite phenomena by the aid of analogies and the numerical verification of their results. The mode of progress has thus veered from the analytical to the synthetical, from the powerful inverse analysis of Laplace and Lagrange to methods more akin to those which were worked by Newton.

It may be stated as a general rule that the relations most directly intelligible and most flexible in this kind of application are properties of constancy, or of maximum and minimum, such as belong in fact to the more obvious features of the continuous growth of pure quantity. The conservation of energy, of linear momentum, of angular momentum, the minimum energy criterion of equilibrium, of steady motion, the maximum and minimum energy criteria which determine the motion following the application of impulses specified either by their actual amounts or by the velocities they produce at their points of application—these may all be cited in illustration. The crown of the edifice will be Maupertuis's principle of Least Action, whose range of exact application, initiated for dynamics by Lagrange and Hamilton, is now being extended into all departments of physics, thus working out an answer to the question—To what extent can the succession of phenomena in inanimate Nature from instant to instant be treated as governed by a principle analogous to that of minimum expenditure of effort in the sentient world?

The phrase from instant to instant is essential, for a path may—as, for example, a great circle on a sphere—be the shortest between two points within a given range of each other, but may cease to have that property when the starting point and the final point are taken too far apart on it. In a similar way, in statics, a certain region of stability is determined around each position of equilibrium, such that, if the system is not disturbed beyond that region, it will not leave the neighbourhood; while, in dynamics of a particle, such a region is more vaguely determined around each orbit by the nature of the enveloping curves or surfaces of the neighbouring orbits.

From the point of view of the direct appreciation of dynamical ideas, the small books at the head of this article form a very welcome addition to the ordinary text-books. The work of Prof. Perry, popular lecture though it be—and one feels constrained, from the confident style, to believe that his audience of operatives understood every word of it—leads on the reader by vivid illustration into contact with the boldest flights of dynamical speculation. After the ordinary effects of spin have been copiously illustrated, we are taken into a world in which matter has two kinds of inertia; and, by aid of a chain of balanced gyrostats, we learn that a cord cannot ever transmit motion straight on without also twiddling about. It is fortunate for those of us who have to follow or teach mechanical pursuits that this new species of matter is not often heard of, and is only called up in relation to such unnoticeable, and practically insignificant, phenomena as rotation of the plane of vibration of light waves. The relations of ordinary mass to gravitation, and such like are sometimes intricate enough things to discuss; the introduction of a second kind of mass, and that of a vector character, might lead to despair.

The great pioneer in this field of work, of eliciting the concealed dynamical mechanism of tangible phenomena, is, of course, Lord Kelvin, by whom nearly all our knowledge on the subject has been originated, at any rate in its present exact form. Prof. Perry's book is all the more welcome and suggestive, in that it claims to be chiefly a connected account of what he has learned at first hand from the teaching of Lord Kelvin; an account which has possibly not been published before by anyone, at least in a consecutive form.

Prof. Worthington, after an elementary quantitative introduction to dynamical principles, has gone over the part of dynamics of rotation which relates to a single spinning solid, in the manner of a text-book with numerical illustrations; and there is no doubt that a mastery of his explanations would be a very valuable part of the outfit of a student of physics.

J. L.

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## THE MAMMALIA OF BRITISH INDIA.

*The Fauna of British India, including Ceylon and Burma.* Published under the authority of the Secretary of State for India in Council. Mammalia. Part II. By W. T. Blanford, F.R.S. (London: Taylor and Francis, 1891.)

IN our issue of September 27, 1888, we had the pleasure of bringing before the notice of our readers the first part of Mr. Blanford's valuable monograph on the Mammals of British India. The second part, completing this important work, has lately been published. The delay, as is explained in the preface, has been caused by the necessity Mr. Blanford has been under of spending much time in editing the five volumes of the same series that have appeared since the first part of the present work was issued. His labours in this respect have been increased by two unfortunate and unforeseen circumstances—the lamented death of Mr. Francis Day, and the expiration of the leave of Mr. E. W. Oates, in both cases before the termination of the portions of the work, on fishes and birds respectively, upon which they were engaged, and the completion of which has thus fallen upon Mr. Blanford himself.

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